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ABSTRACT

As the thirteenth lesson of the Articulated Multimedia Physics Course, instructional materials are presented in this study guide with relation to internal energy, heat, and temperature. The topics are concerned with collisions, thermometers, friction forces, degrees Centigrade and Fahrenheit, calories, Brownian motion, and state changes. The content is arranged in scrambled form, and the use of matrix transparencies is required for students to control their learning activities. Students are asked to use a magnetic tape playback, instructional tapes, and single concept films at the appropriate place in conjunction with the worksheet. Included are a homework problem set and illustrations for explanation purposes. Related documents are SE 015 963 through SE 015 977. (CC)

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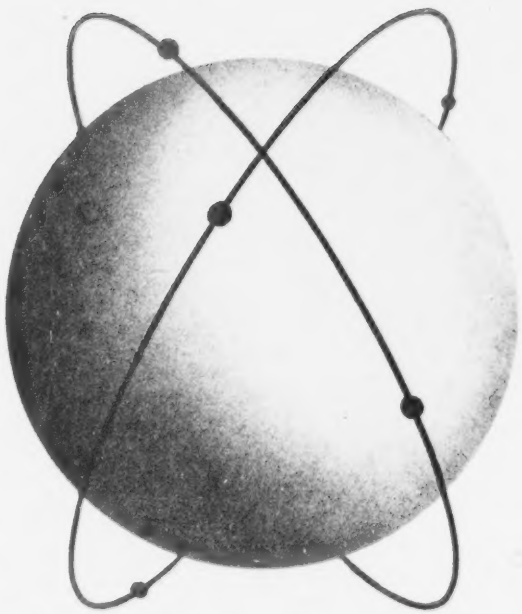
ARTICULATED MULTIMEDIA PHYSICS



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LESSON 13

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OLD WESTBURY, NEW YORK

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NEW YORK INSTITUTE OF TECHNOLOGY

Old Westbury, Long Island

New York, N.Y.

ARTICULATED MULTIMEDIA PHYSICS

Lesson Number 13

INTERNAL ENERGY, HEAT, AND TEMPERATURE

IMPORTANT: Your attention is again called to the fact that this is not an ordinary book. It's pages are scrambled in such a way that it cannot be read or studied by turning the pages in the ordinary sequence. To serve properly as the guiding element in the Articulated Multimedia Physics Course, this Study Guide must be used in conjunction with a Program Control equipped with the appropriate matrix transparency for this Lesson. In addition, every Lesson requires the availability of a magnetic tape playback and the appropriate cartridge of instructional tape to be used, as signaled by the Study Guide, in conjunction with the Worksheets that appear in the blue appendix section at the end of the book. Many of the lesson Study Guides also call for viewing a single concept film at an indicated place in the work. These films are individually viewed by the student using a special projector and screen; arrangements are made and instructions are given for synchronizing the tape playback and the film in each case.

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At the close of our last lesson, we found ourselves in a serious dilemma. Two balls of putty, each with a mass m and a velocity v, roll toward each other from opposite directions, collide head-on, and come to a halt as a result of a stick-together, totally inelastic collision. The energy conservation principle, as we have discussed it thus far, implies that the sum of the potential and kinetic energies after the collision should be the same as the sum of these energies before impact. But this is not so at all. Before the collision, only kinetic energy was present to the extent of $\frac{1}{2}mv^2$ for one ball and $\frac{1}{2}mv^2$ for the other one. That is, the total energy of the system was $\frac{1}{2}mv^2 + \frac{1}{2}mv^2 = mv^2$. You will remember that energy is a <u>scalar</u> quantity; thus, despite the fact that the balls move in opposite directions, no account is taken of the algebraic sign in summing up the energy.

After the collision, however, both putty balls come to rest. So v becomes zero for each ball, making the total K.E. of the system zero. Where did the energy go? Is this a violation of the Principle of Conservation of Energy? Is there something taking place, some event or phenomenon that is obscured by the conditions of the experiment, which might explain the discrepancy?

Please turn to page 144 in the blue appendix.

Recall our introductory work in energy. You will remember that our statement of the conservation principle:

$$\underbrace{\text{K.E.} + \text{P.E.}}_{\text{before}} = \underbrace{\text{K.E.} + \text{P.E.}}_{\text{after}}$$

was predicated on ideal conditions, where friction and air resistance did not exist, and where all collisions were perfectly elastic. An ideal stone falls from a height to the zero reference level without meeting opposition from the air; a block slides on a frictionless table; and two balls collide so that the energy of rebound is exactly the same as the initial energy.

Clearly, these are fictitious conditions. Our world is far from ideal; friction, air resistance, and inelasticity do exist. The collision of the putty balls is an example of an event which appears to undermine the conservation principle only because we have ignored these interfering factors completely.

Please go on to page 3.

Take another example: suppose a block of wood is allowed to slide down a real inclined plane. It starts from height h, and has a mass m. Its potential energy is, then, equal to mgh. It arrives at the bottom of the plane with a velocity v, hence its kinetic energy is $\frac{1}{2}mv^2$. Now, under ideal conditions we should be able to say that:

$$\frac{1}{2}mv^2 = mgh$$

But if we measure the final velocity of the block, we would find that $\frac{1}{2}mv^2$ turns out to be a much smaller quantity than mgh and we would be forced to say that:

$$\frac{1}{2}mv^2 \neq mgh$$

Our aim in this lesson is to learn how to introduce friction and allied phenomena into our thinking about energy conservation. We shall find that the Principle of Conservation of Energy is perfectly valid under all conditions, ideal or otherwise. There is a perfectly legitimate way to introduce the imperfections of our universe into our equations without destroying our previous concepts. Energy is used to produce distortion, and to overcome friction and air resistance, often giving off heat in the process.

With this lesson, we take our first steps out of the world of gross mechanical interactions, where blocks of wood, billiard balls, and carts behave in an entirely visible manner, into the realm where molecules of matter become the subject of our interest and observation.

Please go on to page 4.

A block of wood rests on a real wooden plank as shown in Figure 1.

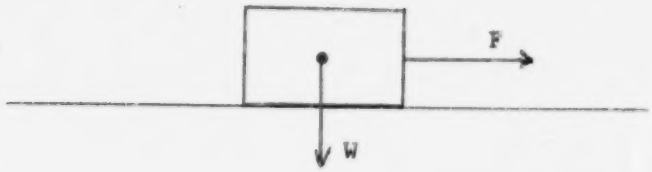

Figure 1

A force F is applied to the block (the weight of the block is W) causing it to move a distance d horizontally toward the right. Clearly, the work done is $W = Fd$, since the direction of the force is also toward the right. That is, work is the product of the distance moved and the component of the force in the direction of motion. (Unless stated, we shall assume that we need not concern ourselves with acceleration; the forces are uniform and the motions occur with constant velocity.)

The weight of the block does not enter into the problem <u>directly</u>, since the weight is a vertical force and has no horizontal component. Yet you know from experience that the weight must have something to do with the force required to move the block horizontally. Should the block be made very much heavier, you would have to exert much more force horizontally to move it.

Then, what part does the weight play here? On the basis of your experience, choose the statement below which can lead to a possible answer.

(1)

A An increase in weight establishes a horizontal force component that did not previously exist.

B An increase in weight causes an increase in mass.

C An increase in weight causes an increase in friction.

YOUR ANSWER --- A

Think for a moment. When someone says the temperature of a room is 75 degrees, does this mean the heat of the room is 75 degrees?

A thermometer may give some indications of the passage of heat from one place to another but it certainly does not measure it.

Please return to page 11. There is another, much better answer available to you.

CORRECT ANSWER: In Figure 1 on page 4, work is being done against friction.

As long as an unbalanced force is required to keep a body moving with uniform velocity, work is being done against something. As for the block in Figure 1 on page 4, the only retarding force is friction, hence work is being done against it.

NOTEBOOK ENTRY
Lesson 13

(Item 1)

(c) When a body is caused to move against friction, work is done. The magnitude of the work is calculated by $W = Fd$, where W is work, d is the distance moved, and F is the component of the force in the direction of the motion.

Thus, when a constant force F is applied to the block, causing it to move a distance d with uniform velocity, the work done is Fd.

Now, if the block moves with uniform velocity when the only retarding force is that of friction, F_f, and the only applied force is F_a, then throughout this motion the block must be in dynamic equilibrium. This tells you how the magnitude of the frictional force must compare with that of the applied force. Once the body is in motion with uniform velocity, then:

(2)

A F_f must be greater than F_a.

B F_f must equal $-F_a$.

C F_f must equal F_a.

D F_f must be smaller than F_a.

YOUR ANSWER --- A

You are correct. This deduction is supported by evidence provided by other natural phenomena and experimental research.

Before continuing, please turn to page 145 in the blue appendix.

Returning to our sliding block of wood, we find that when work is done against friction, the block of wood becomes warmer. The heating of the block has resulted in increasing the average speed of its molecules. Since molecules have mass, what does an increase in speed immediately suggest about the molecules in the heated block?

(8)

A They will have more potential energy than the molecules in the cool block.

B They will have less potential but more kinetic energy than the molecules in the cool block.

C They will have more kinetic energy than the molecules in the cool block.

YOUR ANSWER --- A

Why? Where would the moisture have its source?

It would probably take on an odor if you moved it fast enough, but would that be a moist odor? At the same time you would probably notice something else that caused the odor.

Please return to page 141. Find the real reason.

YOUR ANSWER --- C

You are correct. Since K.E. = $\frac{1}{2}mv^2$, then an increase in average molecular speed must result in an increase in average molecular kinetic energy.

So when we do work in sliding the block against friction, there is an increase in the average kinetic energy of its molecules. This is increased warmth. It is beginning to look as though we may yet save our energy conservation principle! Clearly, the work done against friction does add energy to the system, although this energy is not visible as an increase in either the P.E. or the K.E. of the system as a whole.

NOTEBOOK ENTRY
Lesson 13

2. Work done against friction
   (a) When work is done against friction on a given body, the P.E. and K.E. of the body as a whole do not change.
   (b) Such work results in an increase in the average speed of the randomly-moving molecules of the substance on which work is done.
   (c) Therefore, work done against friction results in an increase of the internal kinetic energy of the substance.

Please go on to page 10.

Before proceeding, we call your attention to a few important items:

First, statement 2(c) of your Notebook Entry does not imply that internal energy is entirely kinetic energy. All we have said is that the internal kinetic energy is increased by work against friction.

Second, we have carefully avoided the use of the word "heat" in a physical sense because it needs further clarification.

Third, we have not used the word "temperature" at all, because this term, too, must be carefully defined and clarified. AT this point we will begin a discussion of heat and temperature.

We must be very careful with words here. We have agreed that an increase in the average K.E. of the molecules of a substance is evidenced in the form of increased warmth. Our fingers are primitive warmth-measuring instruments; they tell us whether item A is warmer than item B, or whether item C has become warmer or cooler than it was previously. A burning pain at our fingertips informs us that we have touched something that is very hot, and so on. But if we want to measure the increased average kinetic energy of the molecules of a substance, we must use something other than our fingers.

Please go on to page 11.

Of course you know what is used. Thermometers are employed to provide us with information concerning molecular kinetic energy. You are familiar with thermometers and have probably handled many types. The wall thermometer, the thermometer in the thermostat control of your oil or gas furnace, the oven thermometer, and the refrigerator thermometer are all everyday objects in most households.

You should have no trouble answering this question: What does a thermometer measure?

(9)

A Heat.

B Temperature.

C Both heat and temperature.

YOUR ANSWER --- B

You are correct. When a thermometer reads 35 degrees on a winter day outside your house, you are perfectly correct when you say that the temperature is 35°. You would not be correct is you said "The heat is 35°."

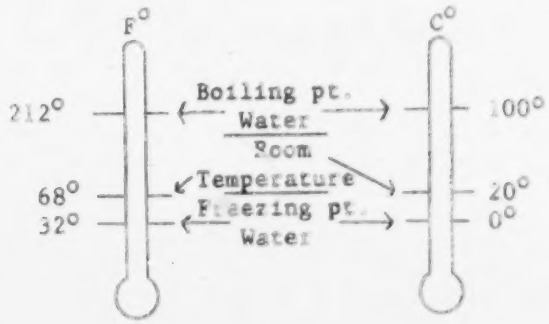

Figure 6

Exactly, what does temperature mean? We'll define the word as a notebook entry, and do the same for heat as well.

NOTEBOOK ENTRY
Lesson 13

3. Temperature and Heat

(a) Temperature is a measure of the average kinetic energy of the molecules of a substance. If the molecules of the substance are single atoms, then temperature is a measure of the average K.E. of the atoms.

(b) Heat is energy in transit from one body to another due to a difference in temperature.

We'll elaborate on each of these in turn. Look at Figure 6.

Two types of thermometers are shown here. One is commonly used by almost everybody in the United States. The other is used in most scientific work, and for ordinary uses in other parts of the world. Which of these thermometers is used for ordinary purposes in the United States?

(10)

A Fahrenheit.

B Centigrade.

YOUR ANSWER --- A

This is incorrect. If both thermometers read the same, then C = F and F = 9/5(C)+ 32 can be rewritten F = 9/5(F) + 32. If you solve this correctly for F, you will not get -17.2°.

Please return to page 18 and be careful with your arithmetic.

YOUR ANSWER --- C

You may have copied this note incorrectly, or you are misinterpreting it.

Item 3(b) does not refer to temperature changes in defining heat.

Please return to page 88. Select a better answer.

YOUR ANSWER --- A

This is untrue. If the answer read: "An increase in weight causes an increase in a certain horizontal force which previously existed but was originally smaller," it would be acceptable. But as it stands, it simply does not correspond to the facts.

What horizontal force component comes into existence as a result of the increase in weight? What kind of force is it? What is its source? You see, if you can answer these questions, you should be able to select the right answer.

Please return to page 4 and select a more satisfactory answer.

YOUR ANSWER --- A

You are correct. When you give the temperature of a room as 70°, you are referring to the Fahrenheit scale.

Because the Centigrade thermometer is gaining popularity, it is always necessary to suffix the numerical reading with either "F" or "C" to indicate the scale. Thus, you should say "70° F" rather than merely "70°."

The Centigrade scale is simpler and more convenient than the Fahrenheit scale and is therefore preferred by scientists. To give you a better "feeling" for the Centigrade scale, we shall derive a simple equation which will enable you to convert a given temperature reading from one scale to the other.

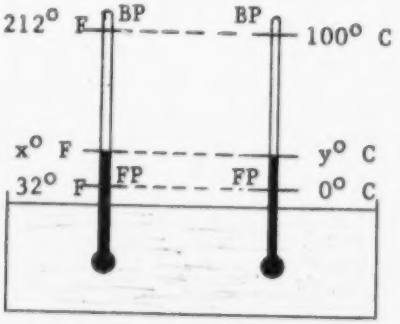

Figure 7

In Figure 7, there are 100 Centigrade degrees between the freezing point (FP) of water and its boiling point (BP). How many Fahrenheit degrees are there between these two fixed points?

(18)

A 212 F°

B 180 F°

YOUR ANSWER --- B

You are quite correct. This answer follows from the division of equations we recommended:

$$\frac{y^{\circ}\ C}{5^{\circ}\ C} = \frac{x^{\circ}\ F - 32^{\circ}\ F}{9^{\circ}\ F}$$

Cancelling units on both sides:

$$\frac{y}{5} = \frac{x - 32}{9} \quad \text{so} \quad y = \frac{5(x - 32)}{9}$$

Since you may have trouble remembering which scale the x and y belong to, we'd recommend that you use the letter C for y and F for x in the form shown in the Notebook Entry below:

NOTEBOOK ENTRY
Lesson 13

(Item 3)

(c) A Fahrenheit degree is 5/9 the size of a Centigrade degree; a Centigrade degree is 9/5 the size of a Fahrenheit degree.

(d) The relationship between a given reading C on one scale and the equivalent reading F on the other scale is:

$$C = \frac{5}{9}(F - 32)$$

where C is the Centigrade reading and F is the equivalent Fahrenheit reading. Going in the other direction:

$$F = \frac{9}{5}C + 32$$

(Note absence of parentheses in last equation.)

Before continuing, please turn to page 146 in the blue appendix.

Here's a simple problem. What Centigrade temperature is the equivalent of 77° F? Work it out, then turn to page 83.

YOUR ANSWER --- B

You're quite right. Here is the solution:

$$F = \frac{9}{5}C + 32 = \frac{9}{5}(-15) + 32$$

$$= -27 + 32 = \underline{5^{\circ}\ F}$$

Notice that the readings of the two thermometers (Figure 7 on page 16) approach each other more closely at lower temperatures.

At the boiling point, the readings are separated by 112 degrees (212 - 100); but at the freezing point, the separation is only 32 degrees (32 - 0). This suggests that at a temperature lower than the freezing point, the two thermometers might coincide. This is true. Can you find the temperature at which the two thermometers would have exactly the same scale readings?

Try to work this out. Here is a hint: when the two thermometers show identical readings, then C = F. One may be substituted for the other in either of our two conversion equations. Does that help? Select the answer below which matches yours.

(16)

A -17.2°

B -25.6°

C -32°

D -40°

YOUR ANSWER --- B

Your notes are in error, or you are misinterpreting them.

Item 3(b) does not refer specifically to kinetic energy. Furthermore, this item makes a point involving the transfer of energy.

Please return to page 88 and select a better answer.

YOUR ANSWER --- A

What might this something else be? How else would you classify heat? We have said that copper is a good condutor of heat.

You see, this answer is a poor one because it implies that there is something mysterious about a situation which is quite simple and straightforward.

The choices available for the situation in the drawing on page 24 are simple enough: (a) either something flows along the copper bar, or (b) something does not flow along the copper bar. If you have reason to think that (a) is true, then you must decide <u>what</u> it is before you throw out energy as a possibility. If nothing flows along the bar as in (b), then the bar will serve no useful purpose, and water temperatures will not change.

We'll let you select another answer. Please return to page 24 and do so.

YOUR ANSWER --- B

No; you have inverted the fractional relationships.

Remember that one $F^{o} = 5/9(C^{o})$. That is, a Fahrenheit degree is smaller than a Centigrade degree, 5/9 of its size on the stem. Hence, a 10.0^{o} increase in C^{o} must include a larger number of Fahrenheit degrees over the same stem distance.

Please return to page 109 and try again.

YOUR ANSWER --- A

Did you recognize that the Fahrenheit change is

$$68.0^{\circ} \text{ to } 203^{\circ} = \text{change of } 135\ F^{\circ}?$$

If you did, then you should realize immediately that the Centigrade change would be numerically much smaller than this, because the Centigrade degree is larger in physical size.

Thus, the answer above is almost the same as 135 numerically, and cannot be correct. You probably added 32° to 203° before you multiplied by the conversion ratio, 5/9.

Please return to page 117; then select a more suitable answer.

YOUR ANSWER --- B

This statement expresses the wrong emphasis. It is much more satisfactory to think of weight as being dependent on mass, not the other way around. Mass is usually taken as the independent variable, while weight is the dependent variable.

Furthermore, admitting that an increase in mass accompanies an increase in weight, this still does not account for the fact that making the weight greater requires a larger constant force to move the block with uniform velocity over the distance d. You may be thinking of Newton's Second Law in which an increase of mass requires a greater force to cause a given acceleration. But in this lesson we are working on the basis of uniform velocity, hence the Second Law is not involved.

Please return to page 4 and select a better answer.

YOUR ANSWER --- A

You are correct. The statement is taken almost verbatim from the notebook entry. Referring to Figure 8, consider two beakers of water at different temperatures "connected" by a solid copper bar as shown.

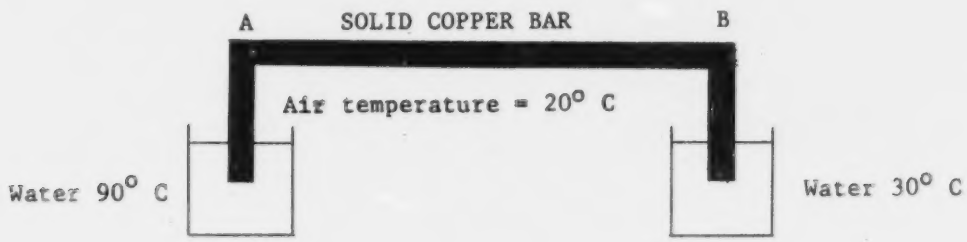

Figure 8

The beaker at the left above contains water that has a higher average internal kinetic energy than the one at the right because its temperature is higher. Copper is a good conductor of heat energy; you may take this for granted.

Now, in view of the definition of heat in Notebook item 3(b) and the conditions shown in Figure 8, what do you think happens?

(20)

A There is no flow of energy at all; something besides energy moves through the copper.

B Internal energy flows from A to B through the copper.

C Heat energy flows from B to A through the copper.

D Heat energy flows from A to B through the copper.

Ice is water in solid form. The molecules that make up the ice are bonded together in a special way to form crystals that are hard and certainly are not fluid. Ice may be converted to liquid water by heating it over a flame. When this is done, heat energy flows into the ice, gradually breaking the bonds between the crystal molecules to transform it into a liquid.

If a thermometer is inserted into crushed ice while it is melting as a result of this flow of heat, a very surprising result is obtained: The temperature of the substance does not change during the melting process, despite the fact that heat is flowing into it. What is the significance of this?

If heat flows into the ice, its internal energy should be increasing. Yet the thermometer shows no increase of temperature. What must we conclude from this?

(24)

A The influx of heat into ice increases only the average speed of its molecules.

B The average internal energy of the resulting ice-water is the same as the average internal energy of the ice before melting.

C The influx of heat into ice does not increase its internal energy.

D The influx of heat into ice does not increase the average kinetic energy of its molecules.

YOUR ANSWER --- A

Right! The energy content of the liquid as a final product is the sum of the internal energy originally in the ice and the heat energy added in the melting process.

We encounter a similar situation when water in its liquid state is heated sufficiently to make it change to steam, the vapor or gaseous state.

Here is a simple experiment to try for yourself. Place a glassful of water in a pan and suspend a thermometer in it. Put it on a stove and heat it. As the water warms from room temperature, the thermometer reading will rise from, say 25° C initially, to 100° C. At or very close to 100° C, the water will begin to boil. To keep it boiling, you must continue to add heat, of course. Yet as you do, you will find that the temperature hovers around 100° C regardless of the high rate of heat flow from the burner into the water. In short, the addition of heat during the boiling process does not increase the average kinetic energy of the molecules (the temperature remains at 100° C), but it <u>does</u> increase the potential energy of the molecules.

For a substance like water, which state has the greater total internal energy when the sample has the same mass and temperature?

(26)

A Liquid.

B Gaseous.

YOUR ANSWER --- A

You slipped up on this.

In the C to F equation, $F = 9/5\ C + 32$. You confused it with the other equation and worked it out as though it read $F = 9/5(C + 32)$.

There are no parentheses in the C to F equation.

Please return to page 83 and work it again, making certain that you don't insert the parentheses.

YOUR ANSWER --- A

This is incorrect.

The heat needed to do this is caluclated from

$$H\ (cal) = m\ (g) \times \Delta t\ (C^{o})$$

All right. The mass is 1,000 g, so m = 1000 g. The starting temperature is 25^{o} C and the final temperature is 100^{o} C. What is Δt, then?

This should be helpful. Please return to page 129 and choose the right answer this time.

YOUR ANSWER --- D

You are absolutely correct. Here's the way to do it:

(1) Heat required to melt 1 g of ice with no change of temperature:

$$1 \text{ g} \times 80 \text{ cal/g} = 80 \text{ cal}$$

(2) Heat required to raise the temperature of 1 g of water from 0° C to 100° C without boiling it: 1 g x $100\ C^{\circ}$ = 100 cal. This is, of course, $H = m\Delta t$.

(3) Heat required to vaporize 1 g of water at 100° C to 1 g of steam at 100° C: 1 g x 540 cal/g = 540 cal. Hence, the total heat added is 80 cal + 100 cal + 540 cal = 720 cal, the correct answer.

In the graph of Figure 10, note that the vertical axis is C° and the horizontal axis represents calories.

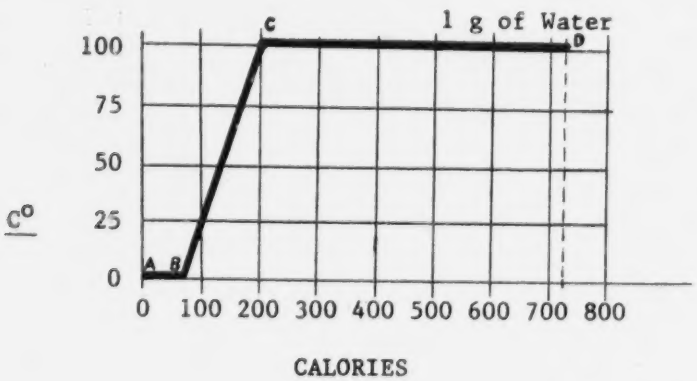

Figure 10

The graph describes the manner in which 1 g of water is made to change its state by a flow of heat. Which of these statements is entirely true?

(30)

A The water is in its liquid state along the entire length of BC.

B The water is in its vapor state along the entire length of CD.

C The water is in its solid state along the entire length of AB.

YOUR ANSWER --- C

The implications of this answer are contrary to all your experience in life. If heat energy flowed from B to A, then the beaker at the right in Figure 8 on page 24 would be adding energy to the beaker at the left. If you know what temperature means, you must conclude that this transfer of energy would cause the temperature of the water in Beaker A to rise, while that of the water in Beaker B falls. In other words, the hot water would get hotter and the cold water colder! Have you ever seen any phenomenon like this actually occur?

No, heat energy would not flow from B to A through the copper.

Try again by returning to page 24, and then selecting another answer.

YOUR ANSWER --- C

You are correct. The force of friction is one of the things one grows up with and almost everyone has an "intuitive" grasp of its meaning, at least in descriptive terms. Let's define friction immediately in a form which will allow us to use it quantitatively, if necessary.

NOTEBOOK ENTRY
Lesson 13

1. Friction

(a) Friction is a force opposing relative motion or the tendency for relative motion of two bodies in contact.

(b) The force of friction is, therefore, a retarding force which acts in a direction collinear with, but opposite to, the direction of the component of force producing or tending to produce motion.

Referring again to Figure 1 on page 4, when the force F causes the block to move horizontally to the right, absolutely no work is being done against gravity since the weight has no horizontal component that can act against the propelling force. But, we agreed that F is an unbalanced, constant force that causes the block to move through the distance d. From our definition of work, we must conclude that work is being done nevertheless; if it isn't being done against gravity, it's being done against something else. What is work being done against?

Write your answer, then turn to page 6.

YOUR ANSWER --- A

You have made a purely mechanical error which you can correct by checking over your algebra.

Make this check, then determine whether or not the other answer given is right, or if the correct answer is something else entirely.

Please return to page 107.

YOUR ANSWER --- C

This is incorrect.

Thermometers are versatile instruments, but not that versatile. A thermometer measures only one of these quantities. Which one?

Please return to page 11. Choose one of the other answers.

YOUR ANSWER --- B

Your answer is incorrect. If you didn't know this from previous science courses in the lower grades, you could have figured it out from the scales.

Refer to Figure 6 on page 12. You know that a 20-degree (20^{o}) reading on the thermometer in your living room or kitchen would indicate extreme cold. Hence, any thermometer that has 20^{o} labeled as room temperature could not be the one to which you are accustomed.

Please return to page 12. Select the alternative answer.

YOUR ANSWER --- A

Sorry, it is not.

In your very last step, you made an error in an algebraic sign.

You can find this mistake. Then turn to page 37 please, and choose the correct answer.

YOUR ANSWER --- B

This is incorrect.

Why should the block increase in size? Did you, perhaps, have expansion due to heat in mind? If so, forget it. If the block expanded at all, the volume increase would be so slight that you could never see it without the aid of delicate instruments.

Please return to page 141 and pick another answer.

YOUR ANSWER --- C

You are correct.

$$F = \frac{9}{5}C + 32 = (\frac{9}{5} \times 60) + 32$$

$$F = 108 + 32 = \underline{140}$$

At temperatures below the freezing point, the Centigrade readings are minus values; therefore, if the temperature is lower than 32° F, the Centigrade thermometer will read minus values. Our equations are just as good for these below-zero conditions as they are for higher temperatures. Let's see how you handle this problem:

What is the Fahrenheit equivalent of -15° C?

(15)

A -5° F

B 5° F

C 9.5° F

D 27° F

YOUR ANSWER --- A

You've missed the point.

When water is vaporized by the addition of heat energy, this heat energy supplements the internal energy already present in the liquid. When the liquid changes to vapor, the energy content of the vapor must be the sum of the original energy present in the liquid plus the heat energy added by the source.

Please return to page 26 and select the alternative answer.

YOUR ANSWER --- A

Refer to Figure 2.

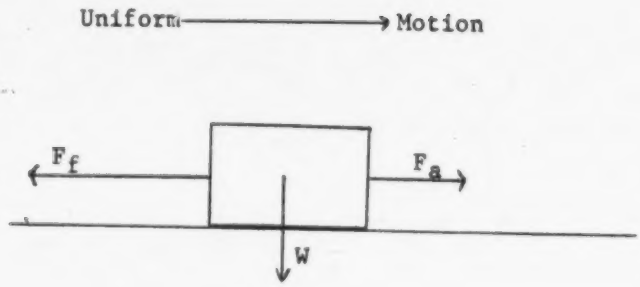

Figure 2

The forces you describe in your answer are shown as vectors. Since the frictional force F_f is to be larger than the applied force F_a, then F_f must be shown as a longer vector than F_a.

Look at the diagram. The fallacy of your answer is immediately evident. If the motion occurs to the right, could the force to the left be <u>larger</u> than the force acting to the right? Of course not. If F_f were greater than F_a, there would be an unbalanced resultant acting in the direction of the larger force. What would such a force do?

Please return to page 6 and find the right answer.

YOUR ANSWER --- C

No, that's not right.

Did you forget that the water starts at 25° C, so that at up to the boiling point is $100^{\circ} - 25^{\circ} = 75$ C°? In other words, the final temperature may be 100° C but the change of temperature is only 75 C°.

Please return to page 129. Choose the right answer now.

YOUR ANSWER --- B

This answer cannot be supported by the facts.

Consider the first part of it: the molecules in the heated object will have less potential energy than those in the cool object. How did you reach this conclusion? We have not mentioned change of position or distortion, so we cannot deduce anything at all about the potential energy of the molecules in either the cool block or the heated block.

In short, you cannot deduce any physical effects or explanations without evidence. But we do have evidence of another effect.

Please return to page 7 and try again.

YOUR ANSWER --- B

That's incorrect. If the blooperium is all vapor, then its thermal condition is pinpointed at point D on the graph on page 139.

You assumed that the cooling started at point C, but this is wrong because at point C we have <u>liquid</u> at 75° C.

Do your calculations again. You should have no trouble now. Return to page 47 and make another choice.

YOUR ANSWER --- B

At the same temperature, the water in each beaker has the same average molecular kinetic energy, but not necessarily the same total internal energy. Why?

Under certain conditions, it is possible for the internal potential energies to be different. If this is the case, we have no guarantee that the total internal energy will be the same in each beaker.

In addition, if the masses of water are different, it is easily shown that the total internal energy in each beaker could not be the same, even with the water at the same temperature. Consider this: at the same temperature, the average kinetic energy of each molecule is the same; but in the beaker containing a greater mass of water, there would be a correspondingly greater number of molecules. Therefore, in this beaker the total internal energy would be greater.

Please return to page 55 and select a better answer.

YOUR ANSWER --- B

You are correct. If the block is in uniform motion, then it is in dynamic equilibrium and cannot be acted upon by any unbalanced forces. Since force is a vector quantity, the force of friction must be equal in magnitude, but opposite in direction to the applied force. That is:

$$F_f = -F_a$$
or
$$F_a = -F_f$$

The choice depends on the direction we call positive.

NOTEBOOK ENTRY
Lesson 13

(Item 1)

(d) If a force is applied to overcome the retarding force of friction in such a way as to cause a body to move with uniform velocity, then the force of friction is equal in magnitude and opposite in direction to the applied force.

$$F_a = -F_f$$

Suppose a force is applied to a cart causing it to move eastward with uniform speed a distance of 3 meters. If 36 joules of work were done, describe the force of friction fully.

(3)

A $F_f = 12$ nt.

B $F_f = -12$ nt, where the (-) sign signifies west.

C $F_f = -12$ nt where the (-) sign signifies east.

YOUR ANSWER --- B

This is incorrect. If both thermometers read the same, then C = F and F = 9/5(C) + 32 can be rewritten F = 9/5(F) + 32. If you solve this correctly for F, you will not get -25.6^{o}.

Please return to page 18 and be careful with your arithmetic.

YOUR ANSWER --- A

This is not true. Refer to Figure 10 on page 29. Consider what governs the slope of CB.

It requires 100 cal along the abcissa axis while the temperature is rising 100 C^{o} to give CB its present slope. If more heat was needed to cause this rise in temperature, then CB would have a gentler slope, and vice versa. Also, if 100 cal of added heat caused a smaller temperature rise, the slope would be gentler.

In short, the slope of CB is a function only of the temperature rise in connection with the amount of added heat; it has no relation to the change of state.

Please return to page 134 and select another, better response.

CORRECT ANSWER: It requires 25 calories to melt ½ g of blooperium.

Let's work the problem in reverse. Referring to Figure 11 on page 139 suppose that you have 12 g of blooperium as a vapor at 75° C. To freeze this vapor, it would be necessary to remove heat by placing the substance in contact with something of much lower temperature, so that heat would flow out of the blooperium into the low-temperature body.

As heat is absorbed from the gaseous blooperium, it would first change to a liquid; the liquid would then cool to the freezing point; finally, the liquid would solidify.

Calculate the amount of heat in calories which must be removed from the 12 g of blooperium vapor at 75° C in order to convert the mass to solid blooperium at 0° C. Then choose the answer that you think is correct.

How many calories must be removed to convert 12 g of blooperium vapor at 75° C to 12 g of blooperium solid at 0° C?

(34)

A 150 calories

B 900 calories

C 1,800 calories

D None of these answers is correct.

YOUR ANSWER --- C

You are close, but we are going to insist upon one little detail that you overlooked. That is, that you must bear in mind constantly the fact that force is a vector quantity. If you say that $F_f = F_a$, you are, in the strictest sense, stating that both F_f and F_a could be represented by the same vector. But they cannot be so represented, can they? Since friction is a retarding force (see Notebook Entry 3b), its direction must be opposite that of the motive or applied force. However, if two forces have opposite directions, even if their magnitudes are the same, they cannot be represented by the same vector; they cannot be said to be "equal to each other." Hence F_f does not equal F_a.

Return to the original question on page 6. There is a better answer you can select.

CORRECT ANSWER: The temperature of the gas rises.

This effect is experienced every time a gas is suddenly compressed. When you pump up your tire, the air inside the tire and pump becomes warm. A diesel engine uses this heat of compression to ignite its fuel mixture. For this reason diesels do not require spark plugs.

Obviously, work is being done on the gas in B of Figure 9 on page 111. The work is, of course, the product of the average force F and the distance moved downward by the piston. This work done on the gas results in an increase of the average kinetic energy of the gas molecules and is evidenced as a rise of temperature. (Incidentally, the potential energy of the gas as a whole is also being increased, just as the P. E. of a compressed spring is raised above the uncompressed level, but this is not our concern here.)

Before continuing, please turn to page 147 in the blue appendix.

Here we do not have an electric stove, or a gas flame, or any other source of initial high temperature, yet the gas becomes hot. Would you say that heating a gas by compression involves a flow of heat?

(22)

A Yes.

B No.

C I don't know.

YOUR ANSWER --- A

This is correct. For actual conditions, total energy is conserved. Work done on a body may become kinetic energy, potential energy, internal energy, or any combination of the three.

It's time for some notes on this.

NOTEBOOK ENTRY
Lesson 13

4. Conservation of Energy for Actual Conditions

(a) In the absence of friction (ideal conditions), the work done on a body is expressed by

$$W = \Delta K.E. + \Delta P.E.$$

(b) However when friction is present (actual conditions), we have

$$W = \Delta K.E. + \Delta P.E. + \Delta \text{internal energy}.$$

(c) The change in internal energy may be largely a change in the average kinetic energy of the molecules, in which case this change will be reflected as a change of temperature of the substance.

(d) It is also possible for the molecular potential energy to change. In this case, the change cannot be detected as a change of temperature.

(e) When a confined gas is compressed, work is done upon it. Part of this input work is converted into internal energy, as evidenced by a rise of temperature.

You may have wondered about the nature of "molecular potential energy" which we have mentioned a few times earlier. Since a complete discussion of molecular P.E. has ramifications that are not a part of this course, our explanation will be brief.

Please turn to page 25.

YOUR ANSWER --- C

You are correct. The graph on page 139 shows that 25 cal will raise the temperature of 1 g of blooperium through 75 C^{o}. Hence, only 1/3 cal is needed to raise the temperature of the liquid through 1 C^{o}.

Before continuing, please turn to page 149 in the blue appendix.

Which of the following statements is entirely true? (Refer to Figure 11 on page 139 to help you arrive at your answer.)

(33)

A Blooperium has a heat of fusion of 75 cal/g and a heat of vaporization of 150 cal/g.

B Blooperium has a heat of fusion of 50 cal/g and a heat of vaporization of 75 cal/g.

C Blooperium has a heat of fusion of 25 cal/g and a heat of vaporization of 75 cal/g.

D None of the statements above is true.

YOUR ANSWER --- B

You are correct.

Refer to Figure 11 on page 139. The heat of fusion is shown by the abscissa length of AB (50 cal). The heat of vaporization is given by the length of CD along the abscissa axis (75 cal). Since 1 g of blooperium is involved, the heats of fusion and vaporization are, respectively, 50 cal/g and 75 cal/g.

How many calories are required to melt ½ g of blooperium? Write your answer, then check it by turning to page 47.

YOUR ANSWER --- A

This answer is incomplete. It is only a partial description of the force of friction, giving its magnitude correctly but omitting any statement about its direction.

We have emphasized the need for indicating the direction of a force in this type of question. One of the other answers does this correctly.

Please return to page 44 and try to find it.

YOUR ANSWER --- B

This answer is incorrect.

You obtained a Centigrade temperature which corresponds to 203° F. You did not find the Centigrade change which is equivalent to the change specified for the Fahrenheit scale.

In short, you didn't answer the question that was asked.

Please return to page 117 and think before choosing another answer.

YOUR ANSWER --- D

You are correct. Experience tells us that when two bodies at different temperatures are connected by certain materials, the hotter one will become cooler while the cooler one will become warmer.

The relative "hotness" or "coolness" of a body is measured by its temperature. Whether you detect the difference in temperature by using the tips of your fingers or a reliable thermometer, it is still the temperature with which you are concerned.

We fix the meanings of our words as follows:

Heat: The flow of energy from a body of higher temperature to a body of lower temperature through some medium which encourages such a transfer. A flow of heat changes internal energy.

Internal energy: The total molecular energy which resides in and remains in the body. A body can lose or gain internal energy, but it is not the internal energy that flows in or out.

Temperature: The average kinetic energy of the molecules of a body as measured by a thermometer. A thermometer gives no indication of the potential energy that may be present at the molecular level.

Suppose the water in both beakers in Figure 8 on page 8 is at room temperature, or 20° C. Which statement below is true?

(21)

A There will be no flow of heat from one to the other.

B Both masses of water will have the same internal energy.

C Heat will flow out of the beakers into the air.

YOUR ANSWER --- B

You are correct. A gas is heated directly by the work done on it during compression. There is no flow of heat from one body to another.

We are now ready to restate the Principle of Conservation of Energy for all conditions, actual or ideal. Let us remind you of the dilemma we were in when we started this lesson.

Under ideal conditions, potential energy may be transformed to kinetic energy (or vice versa) without loss; that is, the gain of K.E. = the loss of P.E., or vice versa. Under actual conditions, where friction exists in any one of its many forms, the work done upon a body is always greater than the gain of K.E. or P.E. that the body experiences as a result of this work. The difference between the work done on the body under actual conditions and the sum of the K.E. and P.E. gain of the body as a whole is the gain of internal energy that occurs on the molecular level.

When conditions are not ideal, which of the following statements expresses the conservation principle in its new form?

(23)

A Work done = ΔK.E. + ΔP.E. + Δinternal energy.

B Work done = ΔK.E. - ΔP.E. + Δinternal energy.

C Work done = Δinternal energy - ΔK.E. -ΔP.E.

YOUR ANSWER --- B

This answer is incorrect.

Perhaps it will be easier for you to understand if we write a description of the melting process like this:

ice + heat energy = water

The final product--the liquid water--is obtained by adding heat energy to the original ingredient, namely the solid ice. So the heat content of the water as a final product is the sum of the heat energy originally in the ice and the heat energy added in the melting process. Thus, the liquid must contain more, not less, total internal energy.

Please return to page 119 and select the alternative answer.

YOUR ANSWER --- B

You are incorrect.

Take any horizontal line of the three values, H, m and Δt: suppose we use H = 24 cal, m = 8 g, and Δt = 3 C^{o}. Substitute these in the equation you chose. Does $m/\Delta t$, which in this case is 8 g/3 C^{o}, result in 24 of anything?

Please return to page 120 and choose another answer.

YOUR ANSWER --- D

Refer to Figure 3.

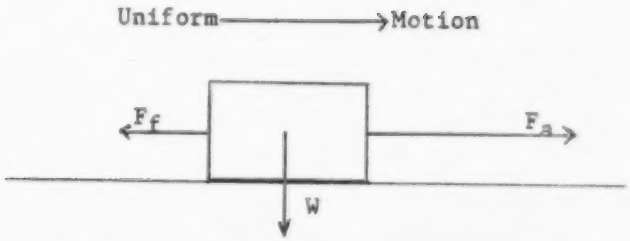

Figure 3

The forces in your answer are shown as vectors. Since the frictional force F_f according to your answer is smaller than the applied force F_a, then F_f must be shown as a shorter vector than F_a.

This representation must be in error, however. The block moves with uniform velocity to the right, according to the given conditions. But, if F_a is larger than F_f, there would be an unbalanced resultant force acting to the right which would cause the block to accelerate. Since the block does not accelerate, Figure 3 cannot represent the true conditions.

Please return to page 6. There is a better answer available.

YOUR ANSWER --- B

You are correct. The vaporization process parallels the melting process in this respect: the liquid has a definite internal energy at 100° C. When heat is added, the temperature remains at 100° C, indicating that the molecular K.E. does not change. The additional influx of heat energy increases the molecular potential energy; hence, the vapor state has greater total internal energy, all other things being equal.

Please go on to page 61.

Since heat is a flow of energy, we should be able to measure it in joules. This can easily be done. However, the gradual accumulation of knowledge concerning heat energy in the early days of physics took a somewhat different course than that of mechanics. This resulted in the development of a different unit of heat measure, the calorie.

Roughly, a calorie is the amount of heat energy that must flow into one cubic centimeter of pure distilled water for its temperature to rise one Centigrade degree.

For example, if 1 cal is added to 1 g of water at 15° C, the temperature of the water will rise to 16° C. If 2 cal are added to 1 g, the temperature will rise 2 C°; if 2 cal are added to 2 g, the temperature will rise 1 C°; if 8 cal are added to 2 g, the temperature will rise 4 C°. From these figures, can you write an equation containing H (heat exchanged), m (mass), and Δt (change of temperature)? Try it, then turn to page 120.

YOUR ANSWER --- A

This can't be right!

If the influx of heat did increase the average speed of the water molecules during the melting process, would not this be equivalent to saying that the average kinetic energy of the molecules increased? Certainly, it would. But the thermometer showed no temperature increase, hence the average kinetic energy could not have risen. This means that the average speed of the molecules did not change, either.

Please return to page 25. Choose a better answer.

YOUR ANSWER --- B

This answer is incorrect because it contains a careless use of terms. Internal energy, consisting of the sum of the molecular K.E. and P.E., resides in the water. The "In-" part of the word "Internal" specifies that this energy is in something. So, if we say that internal energy flows out of the water in Beaker A into the copper bar, it is no longer internal once it leaves the water.

This is another example of fuzziness in language that precise-thinking scientists dislike. Here the misuse or the word "internal" may not be particularly serious. But this sort of imprecision can cause major trouble later on.

Let's be more careful with words.

Select another answer by returning to page 24.

YOUR ANSWER --- C

But one of these answers is correct.

Go back to the original problem to see if you can't find the right answer.

Please return to page 107 and try again.

YOUR ANSWER --- A

This is incorrect. The booiling point of water is 212° F, but the freezing point is 32° F, corresponding to 0° C. To find the Fahrenheit difference, you will have to subtract the freezing point from the boiling point, both in Fahrenheit degrees.

Please return to page 16 and select the right answer.

YOUR ANSWER --- A

This answer is incorrect.

Only 100 C^{o} fit into the space between the freezing point and the boiling point of water on the Centigrade scale, but along the same length of stem we can fit in 180 F^{o}. Since a greater number of F^{o} fit into the same space, then the F^{o} must be smaller than the C^{o}.

Thus, the numerator of the ratio must be a smaller number than the denominator. This means that the ratio must be a proper fraction, not an improper one as in the answer you selected.

Please return to page 74 and try again.

YOUR ANSWER --- C

Sure, that's the answer. This is part of your common everyday experience. The effect of doing work against friction inevitably causes something to get warmer. This phenomenon was used by primitive people to start fires by rubbing sticks together; you unconsciously use it when you rub your hands together for warmth in the winter time.

This suggests the possibility that the work done on the block in sliding it over a rough surface has gone into the production of some kind of energy related to the increased warmth of the block. So, tentatively, we may hypothesize that the heat in the wood is evidence that some kind of energy, which is neither the P.E. nor the K.E. of the block as a whole, has increased in the very structure of the wood. Still hypothesizing, we'll call this internal energy for want of a better term.

To progress further along this line, we must know what form this energy assumes (if it exists at all) and whether or not it is related to ordinary P.E. or K.E. So, at this point, we must briefly follow another bypath in the history of physics.

Please go on to page 68.

In 1827, an English botanist, Robert Brown, made an important discovery. He had placed some pollen grains in water and had dropped the suspension on a slide under his microscope. On examination of the suspension, he was quite sure that he could see each pollen grain vibrating in a random, haphazard fashion.

The kind of motion he observed is illustrated in Figure 5.

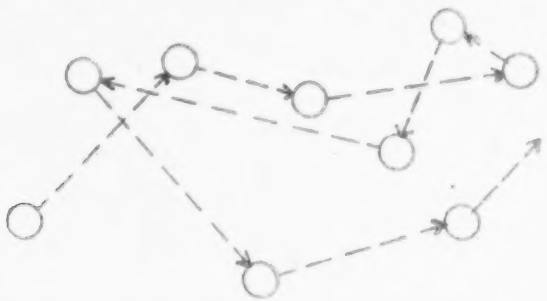

Figure 5

This drawing shows a single pollen grain moving in short straight paths, changing direction and speed in what appears to be a completely random manner. Each grain appears to have been given a life of its own. Naturally, the question arose whether this effect was limited to pollen grains, or whether other very small particles would behave the same way. Robert Brown, as well as others, investigated the phenomenon. It was found that any solid particle of comparative size was affected in the same manner. Thus, "Brownian movement," was found to be due to something occurring in the suspending fluid rather than to a property of pollen grains. What was this something?

Please go on to page 69.

The molecular theory of matter came to the rescue. If the suspending fluid consists of molecules, possibly these might be in rapid, vibratory, random motion, and, in colliding with the solid Brownian particles, might force them to move about as observed. Furthermore, as the suspending liquid was made warmer, the particles became more violently agitated, thus establishing a connection between heat and molecular motion. From this, what would you say is a reasonable deduction?

(7)

A As heat is added to a fluid, its molecules move with greater average speed.

B As heat is added to a fluid, its molecules move with decreased average speed.

C As heat is added to a fluid, its molecules increase in mass.

YOUR ANSWER --- C

You're not thinking this out fully.

If the body moves with uniform velocity toward the east, then the applied force must act toward the east. It is balanced by the force of friction; this explains why the motion is uniform. If F_a were not balanced by F_f, the body would accelerate toward the east.

Therefore, if F_f balances F_a, in what direction must it act?

Please return to page 44 and select the right answer.

YOUR ANSWER --- B

No, this answer doesn't appear reasonable.

Added warmth appeared to agitate the suspended particles with greater violence. Since the agitation was assumed to be due to collisions, "greater violence" means greater rebound speeds, greater momentum of particles, and more kinetic energy per particle.

If heating a fluid causes its molecules to move with decreased average speed, and assuming the mass of each molecule to be constant, how could increased particle speed result from the collisions? Can you see what's wrong with such a conclusion?

Please return to page 69. Choose one of the other answers.

YOUR ANSWER --- D

The correct equation is: $F = \frac{9}{5}C + 32$.

If $C = -15^{\circ}$ C, then the substitutions would look like this:

$$F = \frac{9}{5}(-15) + 32$$

This does not yield 27°. Did you forget about the (-) sign? Did you forget to add 32?

Return to the original problem on page 37. Choose another answer.

YOUR ANSWER --- A

Not necessarily. This conclusion does not follow from the discussion. We have shown only that the average speed of the molecules increases as a result of the heating effect of friction. We have not mentioned change of position or distortion, so we can decude nothing at all about the potential energy of the molecules in either the cool block or the warm block.

Please return to page 7 and select an answer that can be obtained from the facts at hand.

YOUR ANSWER --- B

You are correct. The boiling point (BP) is 212° F and the freezing point is 32° F, so that 212° F - 32° F = 180 F°.

Note that an actual temperature is written as so many "degrees F" or "° F" while an interval between two temperatures is written as so many "F degrees" or "F°." This convention is used for both F and C scales.

There is the same physical distance between BP and FP along the stem of the thermometer on both scales (Figure 7 on page 16). One of these distances contains 180 F°; on the other thermometer there are 100 C° in an equal length of glass stem. Obviously, the C° is larger than the F°, because there are fewer of them in the same distance along the glass.

What is the ratio of the size of a Fahrenheit degree to that of a Centigrade degree? That is, what is the value of the ratio:

$$\frac{\text{size } F^{\circ}}{\text{size } C^{\circ}} ?$$

(12)

A $\frac{9}{5}$

B $\frac{5}{9}$

C Neither.

YOUR ANSWER --- C

Did you notice that the air temperature is also assumed to be 20° C? Thus, everything--beakers, water, air--has the same temperature. This means that the average kinetic energy is the same everywhere. Hence, there would be no tendency for heat to flow out of anything or into anything.

Please return to page 5[illegible]. Then choose another answer.

YOUR ANSWER --- A

This is incorrect.

As the graph on page 139 indicates, 75 cal are required to melt the solid blooperium and then raise its temperature through 75 C^{o}. This isn't close to the requirement for raising 1 g only 1 degree!

Please return to page 95 and select a better answer.

,YOUR ANSWER --- C

This is incorrect. If both thermometers read the same, then C = F and

$$F = \frac{9}{5}C + 32$$

can be written

$$F = \frac{9}{5}F + 32.$$

If you solve this correctly for F, you will not get -32°.

Please return to page 18, and be careful with your arithmetic.

YOUR ANSWER --- B

This is not true. Consider what governs the slope of CB. Refer to Figure 10 on page 29 if you wish. It requires 100 cal along the abcissa axis while the temperature is rising 100 C^{o} to give CB its present slope. If more heat was needed to cause this rise in temperature, then CB would have a more gradual slope, and vice versa. Also, if 100 cal of added heat causes a smaller temperature rise, the slope would be gentler, and vice versa.

In short, the slope of CB is a function only of the temperature rise in connection with the amount of added heat; it has no relation to the change of state.

Please return to page 134; then please choose another answer.

YOUR ANSWER --- D

There's something wrong with your reasoning here. One of the answers certainly does give the right figure. How much heat is required to raise the temperature 75 C°?

Please return to page 95 and choose another answer.

YOUR ANSWER --- B

You are correct. The applied force causes eastward motion. However, the motion is uniform, which shows that there is a balancing force acting toward the west of the same magnitude as the applied force. Thus:

$$\text{Work done on the body: } W = F_a d, \text{ so } F_a = \frac{W}{d}$$

$$F_a = \frac{36\ j}{3\ m} = 12\ nt$$

The applied force is 12 nt. But, $F_a = -F_f$, hence $F_f = -12$ nt. Since we implicitly assigned a positive direction to the eastward force ($F_a = +12$ nt, really), then the force of friction is -12 nt, the (-) sign meaning west.

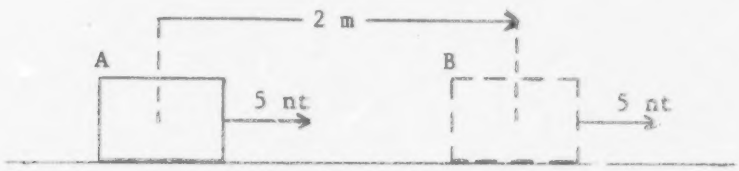

Figure 4

In Figure 4, a 5-nt force causes uniform motion of a block, moving it 2 m to the right. The work done on the block is 10 joules; also, the work done in this case is entirely against friction. When work is done on a body, its energy must change; this is the muscle and heart of the Principle of Conservation of Energy. The block is moving with the same speed as it passes positions A and B (uniform motion) and, furthermore, the block is moving perfectly horizontally. What form of energy change occurs?

(4.

A A change in its potential energy.

B A change in its kinetic energy.

C Neither P.E. nor K.E. changes.

YOUR ANSWER --- A

We disagree!

By definition, heat is energy in transit from one body to another due to a difference of temperature. When a gas is heated by compression, where are the two bodies needed to establish a difference of temperature? Only one "body" is involved here, the gas.

Furthermore, when a gas is heated by compression, how does "transit" occur? Transit implies motion or flow from one place to another. This does not occur here. The increase in temperature results directly from the work done on the gas.

If you wish to review material on this subject turn to page 113.

On the other hand, if you think you are ready to go ahead, turn to page 56.

YOUR ANSWER --- B

This is incorrect.

Here is an analogy to point out the error in reasoning. You are no doubt a firm believer in the Law of Conservation of Money. If you hand a dollar bill to a storekeeper and ask for change, you may get the change in quarters, nickels, dimes, or a combination of all three.

Now, the work done on a body is like the dollar bill, for which you get in "change" some increase of K.E. (quarters), some increase in P.E. (dimes), and/or some increase in internal energy (nickels.)

Suppose the storekeeper offered you 3 quarters, 2 dimes, and 1 nickel in exchange for the dollar bill. To be sure that he followed the Law of Conservation of Money, would you figure it this way?

1 dollar = 3 quarters - 2 dimes + 1 nickel

Not very good, is it? Yet that is exactly what was done in the answer above!

You can see the mistake now, so return to page 56 and choose the right answer.

CORRECT ANSWER: 25° C is the equivalent of 77° F.

In this problem, F is known, that is, F = 77. The reading of C is unknown, so:

$$C = \frac{5}{9}(F - 32) = \frac{5}{9}(77 - 32) = \frac{5}{9} \times 45 = \underline{25}$$

Since C represents the reading on the Centigrade scale, the answer is 25° C.

Try a conversion from Centigrade to Fahrenheit next. Two thermometers, one Centigrade and the other Fahrenheit, are placed in the same warm solution. If the Centigrade thermometer reads 60°, what would the Fahrenheit thermometer read?

(14)

A 166.5° F

B 76° F

C 140° F

D None of these is correct.

YOUR ANSWER --- D

We disagree! One of the statements <u>does</u> give the right figures.

Study the graph on page 139 carefully, taking one point at a time. For example, how many calories are represented by the length of the line showing the heat influx into the solid which causes it to change to a liquid without change of temperature? This <u>is</u> the heat of fusion. Similarly, how many calories are covered by the line showing the vaporization process in which the liquid biooperium changes to a gas without change of temperature? This <u>is</u> the heat of vaporization.

Please try again. Return to page 51 and select the correct answer.

YOUR ANSWER --- C

You solved this by using the equation F = 9/5(C) + 32. The answer is incorrect.

Refer to Figure 7 on page 16 again.

The factor "32" gets into the conversion equations because the two thermometers start at different points. The Centigrade thermometer starts at zero degrees, while the Fahrenheit thermometer starts at 32 degrees. This difference must be taken into account when finding an equivalent temperature on either scale for a reading on the other scale.

However, if you desire to find a change (either a rise or fall) on one scale, which corresponds to a given change on the other scale, then the place where the temperature readings begin has no bearing on the calculations. For example, if there is a rise of 1 C^{o}, there will be a rise of 9/5 F^{o}; if the rise is 2 C^{o}, then the rise will be 2 x 9/5 on the other scale (3.6 F^{o}). Similarly, a rise or fall of 1 F^{o} is equivalent to a corresponding rise or fall of 5/9 C^{o}.

Please return to page 109, and use the above information to help you select the right answer.

YOUR ANSWER --- C

You are correct. The Fahrenheit change (ΔF^{o}) is $203^{o} - 68^{o} = 135^{o}$. Since $C^{o} = 5/9\ (\Delta F^{o})$, then the Centigrade change is $5/9(135) = 75\ C^{o}$.

We hope you now have a reasonable facility for handling temperatures and understand the meaning of temperature in terms of energy.

Let's summarize the important points of this lesson before we continue.

Please turn to page 87.

When work is done on a body against friction, neither the potential energy nor the kinetic energy of the body as a whole changes. The work done against friction results in an increase of the internal energy of the body.

A form of internal energy is the kinetic energy of the individual atoms or molecules of the substance. If the average kinetic energy of the molecules increases as a result of work done on a body against friction, then the temperature of the body will rise. Thus, temperature is a measure of the average kinetic energy of the molecules.

In our choice of words above, we have implied that the internal energy of a body need not be entirely kinetic in nature. That is, internal energy is the sum total of the energies that reside in the substance at the molecular level. Kinetic molecular energy is one of these; as you will see, molecules may also possess potential energy. Hence, by internal energy we mean the K.E. + the P.E. of the atoms or molecules. But remember that a rise or fall of temperature measures only the change in kinetic energy, and that a thermometer does not show changes in molecular potential energy.

Please go on to page 88.

Before going further, let's check on how well you are keeping your notebook.

Look at item 3(b) in your notes for this lesson. Which of the following statements correctly expresses the meaning of this item?

(19)

A Heat is energy in transit from one body to another due to a temperature difference.

B Heat is the total internal kinetic energy of a body.

C Heat is synonymous with temperature change.

CORRECT ANSWER: (a) To melt 4 g of ice at 0° to water at 0° C, 4 x 80 = 320 cal are needed. (b) To bring 4 g of water at 0° C to a boil, 4 x 100 = 400 cal are required. The total influx of heat would then be 320 + 400 = 720 cal.

As you may have anticipated, a similar situation exists when water is vaporized by the addition of heat energy. It requires roughly 540 calories to change 1 g of liquid water to 1 g of water vapor with no change of temperature. That is, starting with liquid water at 100° C, we must add 540 calories to one gram of the liquid to cause it to change to steam at 100° C. This gives us another constant, called the heat of vaporization of water, 540 calories per gram. Thus, to vaporize 2 g of water with no change of temperature, we must add 2 x 540 = 1,080 cal; to vaporize 10 g of water with no change of temperature, we must add 10 x 540 = 5,400 cal, and so on.

Start with 1 g of ice at 0° C. How much heat must flow into the ice to cause it to change to water vapor at 100° C? Work this out in three steps: (1) find the heat needed to melt the ice: (2) then determine the heat needed to bring the ice water up to the boiling point; (3) finally, find the heat needed to vaporize the water and add the three values. What's the answer?

(29)

A 180 cal

B 280 cal

C 640 cal

D None of these is correct.

YOUR ANSWER --- C

You are incorrect.

Take any horizontal line of the three values for H, m, and Δt: Suppose we use H = 24 cal, m = 8 g, and Δt = 3 C^{o}. Substitute these in the equation you chose. Does $\Delta t/m$, which in this case is 3 C^{o}/8 g, result in 24 of anything?

Please return to page 120. Then please choose a better answer.

YOUR ANSWER --- B

No, that's not right. Here is where you made your mistake:

The correct equation for a C to F conversion is

$$F = \frac{9}{5}C + 32$$

Did you use a minus (-) instead of a plus (+) sign in the equation you solved.

Please return to page 83. Correct your work and see if any of the other answers we've given are correct.

YOUR ANSWER --- A

This is incorrect.

You forgot to include the heat of vaporization in your calculations.

Please return to page 89 and work the problem out once more. Then select one of the answers given.

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- B

Heat is energy in transit! There is a flow of heat into the ice, hence there is a flow of energy into it. This influx of energy does not change the speed of the body of ice, nor its mass, nor its height above ground. In other words, the heat does not alter the gross K.E. or P.E. of the body of ice.

Well, then, what happens to this added energy? It must increase the internal energy of the substance, hence the ice-water must have a greater internal energy than the ice before it melted.

Please return to page 25 and select a better response.

CORRECT ANSWER: The boiling point of blooperium is $\underline{75^{\circ}\ C}$.

This is determined simply by inspection. Refer to Figure 11 on page 139.

If DE is the vapor "line," then the liquid must have been boiling all along CD without change of temperature. Hence the ordinate value of CD must be the boiling point--clearly 75° C.

How many calories are needed to raise the temperature of 1 g of blooperium liquid 1 C°?

(32)

A 75 calories.

B 25 calories.

C 1/3 calorie.

D None of these answer is correct.

YOUR ANSWER --- B

Line CD on the graph of Figure 10 on page 29 represents the addition of heat needed to vaporize 1 g of water at 100° C to 1 g of steam with no change of temperature. We know that 540 cal are needed to vaporize 1 g of water, so that by the time we arrive at point D on the graph, all the water has been changed to steam.

Now consider the conditions when only half of this number of calories has been added (270 cal). This would bring the water to the middle of line CD. If 540 cal can vaporize 1 g of water, then 270 cal can vaporize ½ g of water. Thus, at the center of CD, the water is 50% liquid and 50% vapor.

That's why this answer is incorrect.

Now return to page 29 and select a better answer.

YOUR ANSWER --- A

A change in potential energy can occur only if there is a change of position relative to a reference zero height, or if there is a change in the distortion of the block. Neither of these is detectable here.

The block moves horizontally, hence there is no change in its height above ground, which is our reference zero level.

The block does not change shape or form in any way, hence there is no increased or decreased distortion.

Thus, basing our decision on these criteria--criteria established on the basis of both experiment and theory--we must conclude that there is no change in the potential energy of the block as it moves from A to B at constant speed, even though work has been done upon it.

Please return to page 80. Think over the question again. Then choose another answer.

YOUR ANSWER --- C

One of the given answers is correct.

If 180 F^{o} fit into the same space as 100 C^{o}, then the ratio of the size of the F^{o} to the size of the C^{o} is 100 to 180 since the F^{o} is smaller than the C^{o}.

This ratio will reduce to one of the fractions given.

Please return to page 74 and make another selection.

YOUR ANSWER --- C

This answer appears as if you have the conversion backward.

Take another look at the equation, put the numbers in the right places, and do the operations in the right order. If you do your work carefully, you'll come up with the right answer.

Please return to page 37 and try again.

YOUR ANSWER --- D

Hold on, now!

Are you saying that the mass of the block has increased? That's the only thing that could cause it to become heavier.

Maybe you have been misled by ideas about Einstein's equation relating energy and mass: $E = mc^2$. If you have, and if you think that the work done on the block changes to mass, you have been confused by a very common failing: you have allowed your thinking to follow bypaths about which you do not have enough information. It is true that $E = mc^2$. This statement, however, has very special applications under very special conditions. It cannot reasonably be applied to the sliding block.

No, the weight of the block would not increase noticeably.

Please return to page 141; find the one good answer.

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This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- C

It is <u>not</u> reasonable to make this deduction.

Our experience with objects at rest or moving with usual speeds has led us to believe that mass is one of the most constant things in the universe. The block of wood we mentioned before did not increase in size. The fact that the motion of Brownian particles is visible to the unaided eye indicates that the speeds involved are certainly classifiable as usual. (You may know that mass does change measurably when bodies move at velocities approaching that of light, but we are not involved in any such situation here.)

Thus, there is no reason to reach the conclusion you did.

Please return to page 69. Choose a better answer.

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- D

No. That is not right. One of the answers is quite correct. Take a bit more time to think this out.

What would be the effect on the graph on page 29 as a whole if the temperature of water should rise, for example, while it is changing from the liquid to the vapor state?

Please return to page 134 and choose a better answer.

YOUR ANSWER --- B

There might be a change of kinetic energy if the mass of the block changes or if its speed varied. That is, the value of its $\frac{1}{2}mv^2$ can alter only if there is a change in either m, v, or <u>both</u>.

The conditions of our problem do not permit either of these factors to change. There cannot, therefore, be a change in the kinetic energy of the block as it moves from A to B at constant speed, even though work has been done upon it.

Please return to page 80. You can think this out. Select the only answer that makes sense.

YOUR ANSWER --- B

You are correct. Since 100 C^o occupy the same stem length as 180 F^o, then the F^o must be 5/9 as large as the C^o. It would be well to commit this fact to memory.

Refer to Figure 7 on page 16. Suppose both thermometers are dipped into the same water bath. Clearly, the mercury column will rise to the same height in each, say to x^o F and y^o C. To find a relationship between the two scales, we first note that the stem length between 32^o F and x^o F is the same as the stem length between 0^o C and y^o C, so we may write:

$$x^o \text{ F} - 32^o \text{ F} = y^o \text{ C} - 0^o \text{ C}$$

or simply

$$C = x^o \text{ F} - 32^o \text{ F} \qquad \text{(equation A)}$$

But we also know that

$$5^o \text{ C} = 9^o \text{ F} \qquad \text{(equation B)}$$

Now, divide equation A by equation B and solve for y in terms of x. Simplify, then compare your answer with those below. Select the one which corresponds with yours if it is there.

(13)

A $y = \frac{5x - 32}{9}$

B $y = \frac{5(x - 32)}{9}$

C Neither of these is correct.

YOUR ANSWER --- B

You forgot something.

As the graph on page 139 shows, 25 calories are required to raise the temperature of blooperium (a gram) through 75 C^{o}. But that is not the question. We want to know the number of calories needed to raise the temperature of 1 g of blooperium 1 C^{o}.

Please choose another answer after returning to page 95.

YOUR ANSWER --- D

You are correct. Here is the solution: if the thermometers read the same, then C = F and F = 9/5(C) + 32 can be rewritten F = 9/5(F) + 32. Solving for F:

$$F - \frac{9}{5}F = 32 \quad \text{or} \quad \frac{-4}{5}F = 32$$

$$\text{and so} \quad F = -40^{\circ}.$$

As a check, substitute the value -40 for F in the relation

$$C = \frac{5}{9}(F - 32)$$

$$C = \frac{5}{9}(-40 - 32) = \frac{5}{9}(-72)$$

$$C = -40^{\circ}$$

The equations in Notebook Entry 3(d) are restricted to determining equivalent temperatures on the two scales. Given a certain Fahrenheit temperature, you can find the equivalent Centigrade temperature by means of C = 5/9(F - 32); given a definite Centigrade temperature, you can determine the equivalent Fahrenheit reading by means of F = 9/5(C) + 32.

Now, here's an operation in which the equations are not used: A C° and a F° thermometer hang in the same room. If the temperature as indicated by the C° thermometer shows a rise of 10.0°, what rise will be indicated by the F° thermometer?

(17)

A 18.0°

B 6.6°

C 50.0°

YOUR ANSWER --- A

You are correct. Heat flows from one body to another only if there is a difference of temperature between them.

A kettle of water is placed on an electric range. When the range is switched on, the temperature of its heating element rises and heat flows from the element into the kettle, then into the water. This is a true flow of heat due to a difference of temperature. Obviously, the temperature of the water rises.

The same thing occurs when a closed metal vessel containing air, or any gas, is placed on the range element. Heat flows from the hot element, to the vessel, and into the gas, causing its temperature to go up. We visualize the molecules of the gas gathering speed in their random motion as this takes place. The number of collisions increases, the agitation becomes more and more violent, and the average kinetic energy of the molecules climbs correspondingly.

Please turn to page 111.

Refer to Figure 9. In A, a pump-like device having a thermometer near the bottom of the cylinder is shown with its piston raised.

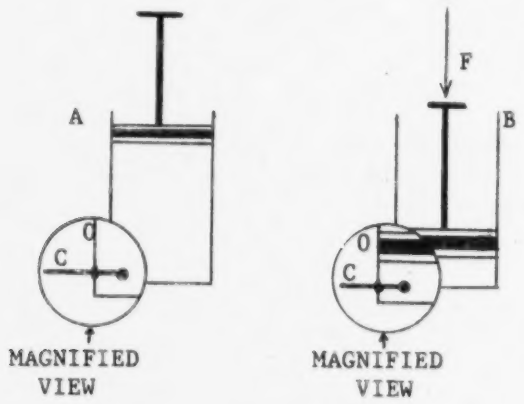


Figure 9

In B, a force F is applied downward on the piston handle, causing the latter to compress the air in the cylinder.

From your experience with similar devices (and from the indications in the diagram) what happens to the temperature of the gas on compression?

Please turn to page 49.

YOUR ANSWER --- C

No, that is not correct.

You forgot to include the heat of fusion in your calculations. Remember that there are 3 steps in this calculation. Check your work, then choose the best answer.

Please return to page 89.

YOUR ANSWER --- C

Look at the definition of heat given in Notebook item 3(b)! Heat is energy in transit from one body to another due to a difference of temperature.

Essentially, this definition of heat sets up certain restrictive conditions; only when these conditions are met can we apply the word "heat" to any phenomenon in which there is a change of internal energy.

First, transit requires motion. Unless energy moves from one place to another, we cannot speak of it as heat.

Second, two bodies must be connected in such a way that energy can pass from one to the other. The copper bar connecting our two beakers of water (Figure 8 on page 24) is one such system; a pot above a flame is another.

Third, there must be a difference of temperature between the two bodies. It is this temperature difference which sets up the final condition needed for a flow of heat.

When a gas is heated by compression, none of these restrictive conditions are met. Energy does not move from one place to another. Only one body is under consideration, namely, the mass of gas. There is no initial temperature difference.

Please return to page 49 and select the right answer.

YOUR ANSWER --- C

This is incorrect.

Here's an analogy to point out the error in reasoning. You no doubt expect money to be conserved when you get change for a dollar bill. That is, you expect the value of the quarters, dimes, and nickels you get in exchange for your dollar bill to total 100 cents.

Work done on a body is like the dollar bill. When you put work into some action, if energy is to be conserved you expect to get some change of K.E., possibly some change in P.E., and some change in internal energy.

Suppose the storekeeper offered you 2 quarters, 3 dimes, and 4 nickels in exchange for the dollar bill. To be sure that he had faithfully followed the Law of Conservation of Money, would you figure it as shown below?

1 dollar = 4 nickels - 2 quarters - 3 dimes

That's not very good, is it? Well, the Conservation of Energy principle works in the same way, and for the same reasons!

Now return to page 56 and choose the right answer.

CORRECT ANSWER: You would find the ice water to be at 0° C.

The influx of heat has melted the ice without raising its temperature; the added heat energy has increased the molecular P.E., not the average K.E.

Repetition of this experiment, and others with the same objective, shows that the figure of 80 cal is not an accidental one. Under like conditions, it always takes about 80 cal to melt 1 g of ice at 0° C to 1 g of water at 0° C. This quantity is called the heat of fusion of water; in giving this quantity a name, we are merely recognizing that it is constant and may be used in calculations.

For example, how many calories would be required to melt 6 g of ice at 0° C and bring the final temperature of the ice water to 55° C? This simple problem is handled in two steps:

(a) Each gram of ice requires 80 cal to be converted to liquid at 0° C. There are 6 g of ice, hence the melting process alone requires 6 x 80 = 480 cal.

(b) We now have 6 g of ice water at 0° C. To raise its temperature to 55° C, we reason that 6 x 55 = 330 cal would be needed because each gram demands 1 cal for each degree of rise. ($H = m\Delta t$). Thus, the total number of calories required to raise 6 g of ice at 0° C to water at 55° C is 480 cal + 330 cal = 810 cal.

Try this one: determine the heat influx in calories required to bring 4 g of ice at 0° C to the boiling point. Write your answer, then check your work by turning to page 89.

YOUR ANSWER --- C

You are correct. Despite the unquestionable fact that work is done all throughout its motion from A to B, the block does not gain (or lose) either potential or kinetic energy.

At this point we are forced to make a decision between these possibilities: (a) The Principle of Conservation of Energy insists that any work done on a body must appear as an increase in its energy; since neither K.E. nor P.E. increases in this case, then the conservation principle must be wrong. (b) There is another form of not-so-obvious energy into which the work done on the block is converted.

Now, imagine that you were the first physicist to make these observations and grasp the implications of the simple experiment of moving a block against friction, as in Figure 4 on page 80. What would you decide to do?

(5)

A Discard the Principle of the Conservation of Energy.

B Look for a form of energy other than the gross P.E. or K.E. of the block.

C I wouldn't know what to do.

YOUR ANSWER --- A

You are correct. Since one Centigrade degree is 9/5 the size of a Fahrenheit degree, then given a change on the Centigrade scale, we find the equivalent Fahrenheit change from:

$$F^{\circ} = 9/5 \ C^{\circ}$$

and vice versa

$$C^{\circ} = 5/9 \ F^{\circ}$$

Now let's use the conversions from one temperature scale to the other to solve this last problem.

A Centigrade and a Fahrenheit thermometer, both at room temperature (20.0° C and 68.0° F) are simultaneously plunged into hot water. The final temperature reading on the Fahrenheit thermometer is 203° F. What is the change of temperature of the thermometer in Centigrade degrees? (Copy This Problem)

(18)

A 131 C°

B 95.0 ° C

C 75.0 C°

D None of these answers is correct.

YOUR ANSWER --- D

This is incorrect. One of the answers is correct.

There are several ways to handle this problem. Here are two:

(1) You might find the Centigrade temperature that corresponds to 203° F and then subtract the starting °C temperature from this computed value. This would give you the change asked for in the problem.

(2) You might caluclate the value of the change in F° and convert this change to C°.

In either case, the result is one of the answer choices.

Please return to page 117 and select the right answer.

YOUR ANSWER --- D

Very good! That's quite right. If the average K.E. of the molecules had increased, a temperature rise would have occurred.

But heat is energy, and heat <u>is</u> flowing into the ice as it melts. The internal energy, therefore, must increase, yet the average kinetic energy of the molecules does not! We must conclude that another kind of internal energy increases.

The bonds that hold the molecules together in solid crystals are disintegrated by the energy supplied by the influx of heat. This additional energy is stored in the molecular structure as <u>potential energy</u> when the ice has liquefied. An ice cube dropped into tap water results in cooling because, as the ice melts, heat from the water flows into the ice to melt the solid. The resulting liquid mixture has a lower temperature than the initial tap water, primarily because some of the K.E. of the molecules of the tap water has been converted to P.E. of <u>liquid</u> molecules which once constituted the ice. (Some cooling is due to the fact that the ice had a lower temperature than the water initially, but this effect is minor.)

In which state, solid or liquid, does a given sample of a substance like water at a given temperature contain a greater amount of total internal energy?

(25)

A Liquid.

B Solid.

CORRECT ANSWER: Let's set up a tabulation of the data presented in the question, (plus a little more). Copy this table on your work paper.

Heat added (H)	Mass of water (m)	Temp. change (Δt)
1 cal	1 g	1 C^o
2 cal	1 g	2 C^o
2 cal	2 g	1 C^o
8 cal	2 g	4 C^o
8 cal	4 g	2 C^o
24 cal	8 g	3 C^o
24 cal	6 g	4 C^o
24 cal	3 g	8 C^o

As the table shows, each calorie added to each gram of water causes a 1 C^o rise in temperature. (The reverse is also true. Each calorie removed from each gram causes a drop of 1 C^o in the temperature of the water.) So, if you add 24 cal to 8 g of water, each of the 8 g receives 3 cal, hence each gram rises 3 C^o. But if you add the same 24 cal to only 3 g of water, each gram now receives 8 cal, hence the temperature rise is 8 C^o.

An equation should now be taking shape in your mind. Which of the answers below is correct?

(27)

A The equation is: $H = m\Delta t$

B The equation is: $H = \frac{m}{\Delta t}$

C The equation is: $H = \frac{\Delta t}{m}$

D None of the equations is correct.

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- D

This is incorrect.

One of the equations is certainly correct. You haven't given the problem enough thought.

You must remember that any relationship of m and Δt that you choose must result in an answer equal to the H for that group.

Please return to page 120 and select the answer that satisfies this requirement.

YOUR ANSWER --- D

You're making a mistake somewhere because one of the answers is perfectly correct.

Are you using the right equation? Are your substitutions correct? Did you remember that this equation does not contain parentheses? Are your algebraic signs correct?

Check over these possible sources of error, then return to page 83 and see if you can choose the right answer.

YOUR ANSWER --- B

This answer is incorrect.

You used the number 100 as the heat of vaporization, rather than the correct number.

Check your solution and try to find the error. Then please return to page 89 and make another choice.

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- C

Heat is energy in transit! There is a flow of heat into the ice, hence there is a flow of energy into it. Clearly this added energy does not contribute to the K.E. or the P.E. of the ice as a whole, since it doesn't change its temperature, or raise it to a higher level, or distort its shape.

Well, then, what happens to this added energy? It must increase the internal energy of the substance.

Please return to page 25. One of the other answers is correct.

YOUR ANSWER --- A

One doesn't discard a principle that has stood the test of other experimental and theoretical research before searching for ways to explain the apparent contradiction. If scientists did this, the history of physics would show thousands of generalizations that were rejected and then later were accepted again after further research.

The conservation principle has worked thus far. Isn't it likely that we have overlooked <u>something</u> in the sliding block experiment?

Please return to page 116. Make a better answer selection.

YOUR ANSWER --- C

Refer to Figure 10 on page 29. No doubt you noticed that line AB is 80 calories "long." All along the length of this line, heat is being added to melt the ice. We know that 80 calories are needed to melt 1 g of ice, so that by the time we arrive at point B on the graph all of the ice has melted.

Now consider the situation when only 40 cal have been added, bringing us to the middle of AB. If 80 cal can melt 1 g of ice, then 40 cal can melt ½ g of ice. Thus, at the center of AB the water is 50% solid and 50% liquid.

You can see, then, why this answer is incorrect.

Please return to page 29 and choose a better answer.

YOUR ANSWER --- A

You are correct. The heat exchange required to accomplish a given temperature change of a given mass of water is proportional to both the mass and the change of temperature. The proportion can be converted into an equality because we have defined the unit for H, namely the calorie, as being the heat flow needed to raise the temperature of 1 gram of water 1 degree Centigrade. Since m is unity and t is also unity, then H is unity, too. Thus, a proportionality constant is not required. The equation is:

$$1 \text{ cal} = 1 \text{ g } H_2O \times 1 \text{ C}^\circ$$

Just one simple problem in illustration. A kettle contains 1,000 g of water at 25° C. How many calories will have to be added to the water to raise the temperature to its boiling point?

(28)

A 25,000 cal

B 75,000 cal

C 100,000 cal

YOUR ANSWER --- A

This answer is incorrect. Refer to Figure 11 on page 139. First trace line AB along the x-axis. Note that 50 cal must be added to solid blooperium to change 1 gram entirely to liquid. Next, examine the number of calories required to bring the substance from C to D. This should be helpful in finding the correct answer.

Please return to page 51. Choose a better answer.

YOUR ANSWER --- D

Sorry, but one of the answers is definitely right.

How many calories must be removed from 1 g of vapor to solidify it? Look at Figure 11 on page 139 again. Start at point D and work this out.

Then return to page 47.

YOUR ANSWER --- C

Well, let's see what the problem is.

We have seen the gradual but inevitable growth of the concept underlying the Principle of Energy Conservation. Experiment after experiment conducted under nearly ideal conditions supplied mounting data to confirm the idea that work done on a body results in an increase in its energy. As a matter of fact, we showed that the increase in energy is exactly equal to the work done in lifting a body, or speeding it up, under ideal conditions.

Now, in this experiment involving the block sliding along a table against friction, we do <u>not</u> have ideal conditions. Work is being done against friction without any apparent increase in either the K.E. or the P.E. of the block. If you were now to reject the conservation principle because it does not appear to "work" under <u>actual</u> conditions where friction is present, wouldn't you be saying that the theory is impractical or useless? As a good physicist, you should assume, at least in your preliminary thinking, that you have overlooked something; that somewhere, somehow, there is a missing piece to the puzzle, and if you find it, the picture would be correct and complete.

Return to the original question on page 116. Choose another answer based upon the above discussion.

YOUR ANSWER --- B

You are correct. Using $H = m\Delta t$, we have

$$H \text{ (cal)} = 1{,}000 \text{ g} \times 75 \text{ C}^\circ = 75{,}000 \text{ cal}.$$

Incidentally, you will want to know the numerical relationship between the calorie and the joule, since they are both units of energy. Various experiments have been performed over the years to make this determination. At present, the accepted figure is given as:

4.19 joules in one calorie, or
0.238 calorie in one joule.

Either of these ratios may be called the mechanical equivalent of heat. Thus, if 4.19 joules of mechanical work are completely transformed into internal energy, the increase in internal energy would be 1 calorie.

Before continuing, please turn to page 148 in the blue appendix.

Now that we have the definition of the calorie, we can go a bit more quantitatively into the matters of melting ice and vaporizing water. Imagine that you have exactly 1 g of pure ice at 0° C. You then allow heat to flow into the ice, keeping tab on the calories that go into it. At the instant that the last of the ice melts, you read your calorie counter and find that almost 80 cal have been used to melt the ice. You stop the heat-flow and measure the temperature of the newly-formed ice water. What temperature would you find it to be? Write your answer, then turn to page 115.

YOUR ANSWER --- A

You are correct. Refer to Figure 10 on page 29. At point B, all the ice has changed to liquid at 0° C. As heat is added beyond this, the liquid warms up until its temperature reaches 100° C (at point C), and then it begins to vaporize. However, all through the process from B to C, the water remains in its liquid state.

Refer again to Figure 10 on page 29.

If water changed its temperature while it was changing state, then:

(31)

A CF would have a steeper slope.

B CB would have a more gradual slope.

C AB and CD would not be horizontal.

D None of these answers is correct.

You have now completed the study portion of Lesson 13 and your Study Guide Computer Card and A V Computer Card should be properly punched in accordance with your performance in this Lesson.

You should now proceed to complete your homework reading and problem assignment. The problem solutions must be clearly written out on 8½" x 11" ruled, white paper, and then submitted with your name, date, and identification number. Your instructor will grade your problem work in terms of an objective preselected scale on a Problem Evaluation Computer Card and add this result to your computer profile.

You are eligible for the Post Test for this Lesson only after your homework problem solutions have been submitted. You may then request the Post Test which is to be answered on a Post Test Computer Card.

Upon completion of the Post Test, you may prepare for the next Lesson by requesting the appropriate

1. study guide
2. program control matrix
3. set of computer cards for the lesson
4. audio tape

If films or other visual aids are needed for this lesson, you will be so informed when you reach the point where they are required. Requisition these aids as you reach them.

Good Luck!

YOUR ANSWER --- C

You are correct.

Refer to Figure 11 on page 139. Liquefying the vapor (D to C) calls for the removal of 12 g x 75 cal/g = 900 cal. Cooling the liquid (C to b) requires the removal of 12 g x 25 cal/g = 300 cal. Freezing the liquid involves the absorption by the cooler of an additional 12 g x 50 cal/g = 600 cal. Finally, the total heat removed must be 900 cal + 300 cal + 600 cal = 1,800 cal.

We will conclude the formal part of the lesson with a notebook entry.

Please turn to page 137.

NOTEBOOK ENTRY
Lesson 13

5. Potential Energy in Change of State

(a) To convert a substance from its solid to its liquid state without change of temperature, energy must be added to produce the change of state. A liquid of given mass and temperature contains more internal energy, therefore, than the equivalent solid.

(b) To convert a substance from its liquid to its vapor state without change of temperature, energy must be added to cause this change of state. Hence, a vapor of given mass and temperature contains more internal energy than an equivalent mass of the same liquid at the same temperature.

(c) A calorie is the amount of heat that must flow into 1 g of pure distilled water to raise its temperature 1 C^{o}. The mechanical equivalent of 1 calorie is 4.19 joules. The thermal equivalent of 1 joule is 0.238 cal. The heat required to heat any mass of water through any temperature change is given by $H = m\Delta t$, where H is in calories, m is in grams, and Δt is in C^{o}.

(d) Many substances undergo a change of state while absorbing or liberating heat without changing temperature. The heat required to melt 1 g of a substance (or to solidify 1 g by removal of heat) without change of temperature is called the heat of fusion of the substance. The heat of fusion of water is approximately 80 cal/g.

(e) The heat required to vaporize 1 g of a liquid (or liquefy 1 g of a vapor by removal of heat) without change of temperature is called the heat of vaporization of the substance. The heat of vaporization of water is approximately 540 cal/g.

Please turn to page 135.

YOUR ANSWER --- C

You are correct. The horizontal orientation of AB and CD shows there is no change of temperature, despite the addition of heat (see Figure 10 on page 29).

If the temperature did vary while change of state took place, neither AB nor CD could have zero slope as they have in Figure 10.

Many substances other than water display similar characteristics. They liquefy at a definite temperature, requiring a definite number of calories to do so, and change state without change of temperature. The same is true for the vaporization process. These substances, however, do not have the same heat of fusion nor the same heat of vaporization as water.

For an example, please turn to page 139.

Look at the graph in Figure 11.

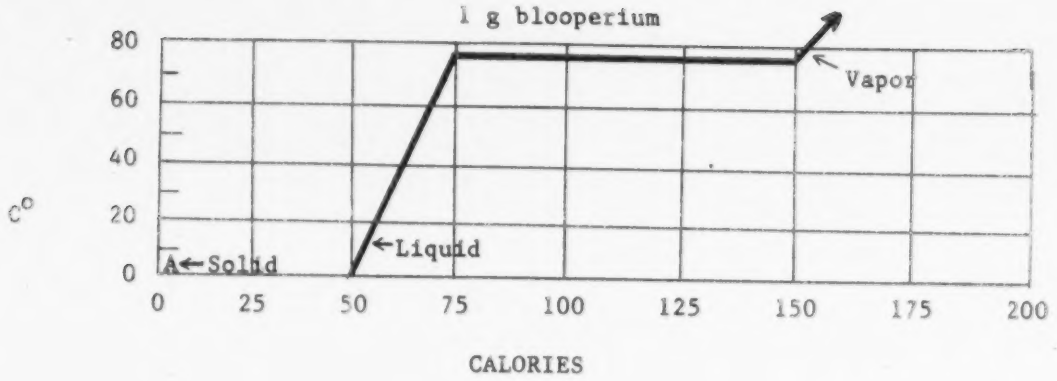


Figure 11

This is a change of state diagram for a Martian substance called blooperium. We can tell many things about the thermal behavior of blooperium from the graph. For instance, its melting point is the same as that of water, 0° C. What is its boiling point? Write your answer, then turn to page 95.

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- B

You are correct.

All right. Suppose we try to find energy other than P.E. or K.E. of the block by sliding it at uniform speed over a really long distance on a rough plank. Thus, the work we do will be large in magnitude since d will be a large number. By doing much work on the block without either raising it or speeding it up, perhaps this mysterious new form of energy will reveal itself.

Let's visualize this. We drag the block on the plank over a distance of 100 meters or 1,000 meters. At the end of the trip, we try to find energy that was not previously there. We smell the block; we feel it with our fingers; we look at it carefully to note visible changes that might have occurred; we might even taste it. In other words, we bring all our natural senses to bear on it in our quest for something that will preserve the conservation principle.

You may have guessed by now what we find.

(6)

A The block has taken on a moist odor.

B The block has increased noticeably in size.

C The block feels warmer.

D The block is heavier.

YOUR ANSWER --- C

No, that's not right. You have the heat of vaporization correct, but you've made an error in the heat of fusion.

Check the graph on page 139 again and find your error in the heat of fusion.

Please return to page 51 and select the right answer.

YOUR ANSWER --- A

This is incorrect. But your error is easily understood. You followed exactly the right procedure to determine the heat that would have to be removed from 1 g of blooperium. However, the question deals with 12 g of the substance.

It should be easy now. Please return to page 47; choose the right answer.

WORKSHEET

Please listen to Tape Segment 1 for Lesson 13 before starting to answer the questions below. Answer selections must be made on the AV Computer Card.

QUESTIONS

Note: This tape segment is a review of momentum considerations involved in perfectly inelastic collisions.

1. Assuming motion to the right to be positive and motion to the left to be negative, the momentum of a 10 kg putty ball moving to the left with a velocity of 3.2 m/sec is

   A -3.2 kg-m/sec^2.
   B -32 kg-m/sec^2.
   C 3.2 kg-m/sec.
   D 32 kg-m/sec.
   E -32 kg-m/sec.

2. The putty ball described in Question 1 collides head on with another putty ball of mass 5 kg moving to the right with a velocity of 3.2 m/sec. The collision is perfectly inelastic. After the collision, the net momentum of the system of putty balls is

   A zero.
   B positive.
   C negative.
   D neither negative nor positive.

3. After the collision described in the tape segment, the net momentum of the system might be described as

   A zero.
   B positive.
   C negative.
   D neither positive nor negative.

4. Does this collision represent a violation of the Principle of Conservation of Momentum?

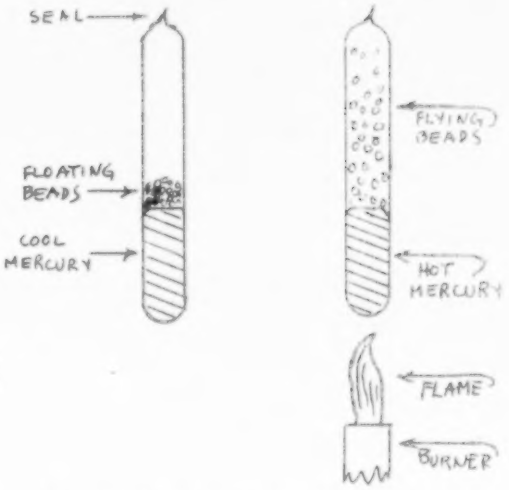
   A Yes.
   B No.
   C Maybe; data is insufficient to tell.

Please return now to page 2 of the STUDY GUIDE

WORKSHEET

Please listen to Tape Segment 2 for this lesson before starting to answer the questions below. Answer selections must be made on the AV Computer Card.

QUESTIONS



5. In the diagram at the right, glass beads are floated on mercury. The experiment described in Tape Segment 2 does not work nearly as well when glass beads are floated on water. Why? Choose your answer from the statements below:

A The molecules of a metallic substance move faster than the molecules of a nonmetallic substance at a given temperature.

B Mercury is an element while water is a compound. The kinetic theory does not apply to compounds.

C Mercury molecules have a large number of electrons in each atom, giving the molecules large kinetic energies.

D Each mercury molecule has a relatively large mass while the mass of a water molecule is much smaller.

6. As one watches the dance of the glass beads, one can see many of the beads falling toward the surface of the mercury at a given time. Often, a bead will bounce upward again <u>before</u> reaching the surface of the liquid. This is caused by

A the collision of an air molecule with the bead.
B agitation at the liquid surface.
C the collision of a mercury vapor molecule with the bead.
D the collision of liquid mercury molecules with the bead.

Please return now to page 7 of the STUDY GUIDE.

WORKSHEET

Data Item A: (STEP 1) $\frac{Y}{5} = \frac{X - 32}{9}$

(STEP 2) $\frac{C}{5} = \frac{F - 32}{9}$

(STEP 3) $\frac{9C}{5} = F - 32$

(STEP 4) $F = \frac{9}{5}C + 32$

QUESTIONS

7. Normal room temperature on the Centigrade scale is taken as 20°. What is normal room temperature on the Fahrenheit scale?

A 70°
B 68°
C 72°
D 75°
E 65°

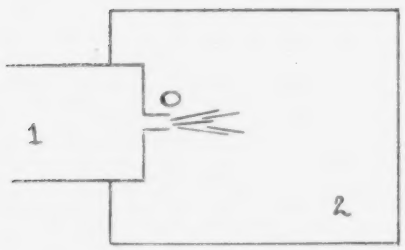
8. Which of the figures below is the closest approximation to absolute zero on the Fahrenheit scale. Absolute zero on the Centigrade scale is -273°C.

A -523°
B 459°
C 523°
D -459°

Please return now to page 17 of the STUDY GUIDE

WORKSHEET

Data Item A: Refer to the diagram below



QUESTIONS

9. In the diagram at the left, a gas is shown expanding outward from chamber 1 into chamber 2 through orifice O. During the expansion process, the pressure due to the gas is

   A higher in chamber 1 than in chamber 2.

   B higher in chamber 2 than in chamber 1.

   C the same in both chambers.

10. Suppose that the gas in chamber 1 had a temperature of 25°C just before expansion began. Assume also that all of chamber 2 is at the same temperature. Immediately after the expansion process has ended, one would expect that the temperature in chamber 2 would be

   A higher than 25°C.
   B between 77°F and 80°F.
   C between 80°F and 100°F.
   D between 90°F and 95°F.
   E between 77°F and 0° F.

Please return now to page 49 of the STUDY GUIDE.

WORKSHEET

Data Item A: Determination of the number of BTU's in one calorie:

1 BTU = heat needed to raise the temperature of one lb of water through 1 F^{o}.

1 lb has a mass of 454 grams and 1 $F^{o} = \frac{5}{9}$ of 1 C^{o}.

Thus, 1 BTU = heat needed to raise 454 g of water through 5/9 C^{o}.

So 1 BTU must contain 454 x $\frac{5}{9}$ calories.

QUESTIONS

11. One British Thermal Unit is the equivalent of approximately

A 200 calories.
B 225 calories.
C 252 calories.
D 273 calories.
E 296 calories.

12. If 1,260 calories added to a mass of water causes the temperature of the water to rise 1 F^{o}, what must have been the mass of the water?

A 1 lb.
B 5 lb.
C 2.52 lb.
D 4.54 lb.
E 1.26 lb.

Please return now to page 133 of the STUDY GUIDE.

WORKSHEET

Data Item A: The specific heat of a substance is the number of calories required to raise the temperature of 1 gram of the substance through 1 C^{o}. The specific heat of water is 1 cal/g/C^{o}.

Data Item B: The Table below gives the specific heats of a number of common substances, in cal/g/C^{o}.

Substance	Sp ht (c)	Substance	Sp ht (c)
water	1.00	iron	0.11
alcohol	0.58	mercury	0.03
aluminum	0.21	platinum	0.03
ammonia (liquid)	1.13	silver	0.06
copper	0.09	zinc	0.09

Data Item C: The quantity of heat (Q) required to raise the temperature of a given mass of any substance (m) over a temperature range (Δt) is given by the expression:

$$Q = m c \Delta t$$

Q will be in calories if m is in grams, c is in cal/g/C^{o} and Δt in C^{o}.

QUESTIONS

13. In the Table in Data Item B, which solid metal requires the least amount of heat for a given rise of temperature?

A aluminum
B copper
C zinc
D mercury
E platinum

14. Of the substances shown in the table, which one would serve as the best coolant, all other things being equal?

A water
B alcohol
C liquid ammonia
D mercury

15. Which one of the above substances is second from the best coolant?

A water
B alcohol
C liquid mercury
D liquid ammonia

16. If enough heat is added to a sample of mercury to raise its temperature by 1 C^{o}, what temperature rise would you expect if the same heat were added to a sample of silver of the same mass?

A 2 C^{o} B 1/2 C^{o} C 1 C^{o} D 4 C^{o}

Please return now to page 51 of the STUDY GUIDE.

AMP LESSON 13

HOMEWORK PROBLEMS
Lesson 13

1. A box is pushed along a horizontal floor a distance of 80 meters. If the retarding force due to friction is 120 nt, how much heat in calories is produced? (Hint: the mechanical equivalent of heat is 0.24 joule/cal)

2. If you rub your hands together rapidly 5 times a second, exerting a force of 60.0 nt through a distance of 20 cm each time (10 cm up and 10 cm down), how many calories of heat will you generate each second?

3. What will the reading of a Centigrade thermometer be when placed in the same water bath containing a Fahrenheit thermometer which registers 140 degrees?

4. When placed in a water bath, a Centigrade thermometer shows a rise of 25 degrees starting from room temperature. What rise will be displayed by a Fahrenheit thermometer transferred from the room into the same bath?

5. If heat is transferred to a mass of water at the rate of 750 cal/min for 10 minutes causing the temperature of the water to rise from 23°C to 48°C in this interval, what was the mass of the water used?

6. Wood alcohol has a specific heat of 0.60 cal/g/C°. Given equal masses of water and alcohol at the same temperature in similar containers, both containers are then transferred to a warm room where each of them absorbs 5.0 cal of heat during the first minute. If the temperature of the water rises 2.4 degrees as a result, what will be the rise of temperature of the alcohol? (Neither liquid reaches the temperature of the warm room during this time).

7. How many calories are required to raise 10.0 g of water from 2.00° C to 98.0°C?

8. How many calories are required to convert 10.0 g of ice at zero degrees C to 10.0 g of water vapor at 100 degrees C?

9. The specific heat of aluminum is 0.21 cal/g/C°. How much heat in calories is required to raise 20 g of aluminum from 12°C to 30°C.

10. A 10-lb mass is dropped from a height of 50 ft. If all the energy is converted to heat, how many BTU will be produced? (Note: the mechanical equivalent of heat in the English system is 778 ft-lb/BTU.)